PRESENT STATUS OF DISINFECTION OF WATER SUPPLIES

By Francis F. Longley

The treatment of water by disinfection has had a remarkably rapid growth and has come to be a popular and widely known subject. So much has been written and said upon this in the last few years that it is with some hesitation that the writer approaches the subject. In most phases of it there is danger of a great deal of repetition. There are a number of points, however, upon which recent occasion has arisen to make rather extended inquiry, and the following is intended to embody some of the results of this study.

This information was brought together through the circulation of a large number of inquiries intended to cover the field of disinfection in reasonable fullness. A list of the water supplies in the United States and Canada, in which some method of disinfection was known or believed to be used, was prepared from all available sources. Although the hearty coöperation of engineers, health officers and others was secured in a great many cases, there can be no assurance that the list was complete.

The total number of inquiries sent out was about 240. Replies were received to about 110, or nearly half. These replies represent in the aggregate water supplies of somewhat more than 2000 million gallons per day.

The information is given herein largely in statistical form, and, of course, relates only to the supplies regarding which replies were received.

Some of the inquiries were directed at the less used methods of sterilization, such as ozone and ultra violet rays, but so little information in reference to these was forthcoming that the writer is not disposed to say anything further in regard to them herein than that their development is not far enough advanced at the present time to justify the expectation of success in the near future which will permit them to displace the use of hypochlorite and liquid chlorine to any considerable extent.

Of all the replies received about 80 per cent are stated to use, or to have used, hypochlorite of lime, and the balance liquid chlorine.

About 75 per cent of the supplies regarding which information was received are river waters; about 20 per cent are from lakes, and the small remainder are ground waters.

The first application of hypochlorite noted among the replies was in 1908, in which year disinfection by this means was begun at the Bubbly Creek plant at the Union Stock Yards in Chicago; at the Boonton reservoir of the Jersey City supply, and upon the municipal water supply of Poughkeepsie, New York. The several years following showed a rapid increase in the number of installations, although the records of 1913 indicate a falling off. The rates for the year 1914 are incomplete. Of the total installations regarding which replies were received, the percentages installed each year have been as follows:

1909, 13 per cent, representing a total of 100 million gallons per day.

1910, 14 per cent, representing a total of 450 million gallons per day.

1911, 22 per cent, representing a total of 320 million gallons per day.

1912, 22 per cent, representing a total of 710 million gallons per day.

1913, 18 per cent, representing a total of 70 million gallons per day.

1914, 8 per cent, representing a total of 265 million gallons per day.

Some 37 per cent of the cities replying use a disinfection without other treatment. The balance use it as an adjunct to some treatment, in most cases filtration. In 57 per cent of those cases in which it is used as an adjunct to filtration, it is used as a final treatment. In 26 per cent it is used after coagulation or sedimentation and before filtration. In the remaining 17 per cent it is applied before coagulation and filtration.

The data at hand do not give any reasons for the application before coagulation. In general, an effective disinfection may be secured with a smaller quantity of hypochlorite if it is applied after rather than before filtration. It should be noted that the storage of chlorinated waters in coagulating basins and their passage through filters tend to lessen tastes or odors contributed by the treatment,

and this fact may in some cases account for their use in this way. Beyond this there is nothing in the moderate amount of bacterial data secured in connection with this work that enables us to generalize upon the relative advantages of these different points of application.

The cost per million gallons for the equipment required for this treatment varies widely and does not seem to bear any very close relation to the capacity. The cost per million gallons as stated, varies all the way from $4 to $2400. These variations are accounted for by the fact that designs for equipment of this sort vary widely. Some are the merest makeshifts, while others are elaborate. Some of the costs quoted include no building costs, while others include expensive structures. Taking the figures as they stand, as the data do not permit any further analysis, the total costs per million gallons are stated not to exceed $25 in 12 per cent of the supplies, $50 in 30 per cent, $100 in 42 per cent, $250 in 67 per cent and $500 in 87 per cent of the supplies about which information is available.

The total cost per million gallons for the process also varies widely. By far the greater number of costs stated lie between 10 cents and 50 cents per million gallons, the average for these being about 25 cents.

The information at hand indicates that the commonest construction of tanks for hypochlorite is concrete. Some 67 per cent of the supplies stated that they had either concrete tanks or tanks of wood or iron relined with concrete. Something more than 20 per cent are of wood without lining. The balance are either wood with lead lining, wood or iron with some protective or acid resisting paint, or porcelain lining. The liquid chlorine is universally contained in special iron cylinders.

The piping seems in general to have been put together of the materials most easily available, without regard to corrosion. Fifty-six per cent of the replies indicate the use of iron pipe, either black or galvanized, 15 per cent use lead pipe and about an equal number use brass. A few use lead-lined iron pipe, cast iron pipe, hard rubber, rubber hose, bronze or copper pipe.

The same comments apply to the kind of valves and fittings commonly used. Sixty-six per cent of these are of brass such as are usually found in stock. Some 14 per cent state that bronze valves and fixtures are used, but it is possible that some, if not most of these, upon further inquiry, might prove to be brass. A few use

iron valves or fittings and a few have fixtures made of vulcanite, rubber composition, lead, copper, glass, etc.

The materials commonly used which seem to have shown the greatest resistance to the corrosive effects of hypochlorite are concrete tanks, lead pipe and rubber composition. Several of the answers indicate that copper, cast iron and lead-lined iron pipes are used without corrosion and a number indicate, too, that brass and galvanized iron are used without corrosion. The evidence as to these two last materials, however, is contradictory, as other answers indicate considerable corrosion with galvanized iron and brass. It seems likely that the quality of the material and some peculiar local conditions may, perhaps, be determining factors in the corrosive effect upon these two materials. The results show the unmistakable corrosive effect upon wrought iron and also upon wood.

Evidence has been found in the past of occasional large variations in the strength of commercial hypochlorite. In answer to an inquiry on this point, only 29 per cent indicated that the strength of hypochlorite as purchased had been determined. That this is a point of considerable importance is indicated by the following figures:

The maximum percentage of available chlorine stated was 42 per cent. Numerous others ran as high as 39 or 40 per cent. The minimum stated was 15 per cent, with several others less than 20 per cent. The average strength was 33 per cent. In two cases the maximum percentage strength noted is as large as $2\frac{1}{2}$ times the minimum strength. These variations in quality in the commercial hypochlorite are significant, and it is obvious that the strength should be determined and a correction made in the application, if necessary, if the best results are to be secured.

The low cost and the ease of application of disinfection to water supplies have caused its introduction in a great many places where the records of mortality or morbidity from such diseases as typhoid, which can be used as indicators of the benefits derived, are already so low that no striking improvement can be expected therein. In a large percentage of the cases it seems clear that the application was as a precautionary measure. This fact makes it less easy than might be expected from the large number of cities and towns making use of disinfection to present statistics showing actual benefits resulting therefrom. Among the large number of communities from which information was obtained, about 75 per cent failed to indicate that any improvement in typhoid or other health condition had resulted.

Many of these indicated that no such improvement had been expected. In some cases where there has been an improvement, it is difficult or impossible to discriminate between the effects of disinfection and of filtration.

The following statements show improvements that have resulted in a number of places:

In Cleveland, Ohio, the chlorination of the water supply started in September, 1911. In the six calendar years prior to this the typhoid death rates had varied from 13 to 20.2, with an average of 16.5 per 100,000. In the three calendar years following, the typhoid death rates were from 6.2 to 13.5, with an average of 9.2 per 100,000.

In Yonkers, New York, the analyst in charge of the water supply states that prior to the use of hypochlorite, but with the water filtered through sand filters, two epidemics of dysentery were recorded at times when the water was unusually high in bacteria. Disinfection by means of hypochlorite was put in use early in 1910. Since that time there have been no such excessive bacterial counts and no corresponding epidemics of dysentery.

In Evanston, Illinois, there has been an actual reduction in intestinal diseases, indicated by the statistics of typhoid fever and gastro-enteritis, which appears to have resulted from the application of disinfection. This was first applied in December, 1911. The statistics at hand cover the period of four years prior to this, namely, 1908 to 1911 inclusive; and three years after, 1912, 1913 and 1914. The death rate from typhoid in the former period varied from 24 to 33, averaging 29 per 100,000. In the period since disinfection it has varied from 6 to 15, with an average of 12. The death rate from gastro-enteritis during the former period varied from 25 to 73, with an average of 49 per 100,000, and in the latter period with disinfection varied from 11 to 40, with an average of 30.

In the city of Baltimore there has been a decided reduction in the typhoid mortality since the use of calcium hypochlorite. It was first used in June, 1911. In the five years prior to that, the death rate from typhoid varied from 33 to 42 per 100,000, with an average of 35. In the three years since, it has varied from 22 to 24, with an average of 23.

In Poughkeepsie the disinfection of the supply was first begun in 1908 in the form of hypochlorite applied to the water before sedimentation and filtration. The death rate from typhoid fever for eight years prior to 1908, as indicated by the United States census

reports, varied from 25 to 114, with an average of 54 per 100,000. From 1908 to 1913, with treatment as stated above, the typhoid death rate varied from 10.3 to 33, with an average of 18.5. Since early in the year 1914 the filter effluent has also been treated, first by means of hypochlorite, and latterly by means of liquid chlorine, and the death rate from typhoid fever for that year was 3.4 per 100,000.

Trenton, New Jersey, is one of the most striking cases of improvement due to disinfection. Prior to 1912 the city used the raw Delaware River water. In December, 1911, the authorities commenced to treat the water supply with hypochlorite. During the five years ending with 1911 the annual number of typhoid cases varied from 208 to 343, with an average of 267. During the three years since disinfection has been applied, the number of cases in the city has varied from 45 to 110, with an average of 74.

In Ottawa the water of the Ottawa River was used without treatment until about March, 1912. Its polluted condition was evidenced by the several epidemics of water-borne typhoid that the city had been through just prior to that. Since the disinfection of the supply, Ottawa has had no further epidemics and only a moderate death rate from typhoid.

The city of Hull, with only about one-twentieth the population of Ottawa, lying on the opposite bank of the river, takes its water supply, untreated, from the same channel as does Ottawa and within a few hundred yards of it. In two recent months Hull has had about 200 cases of typhoid fever, as against 28 in Ottawa for the same period.

In Centralia, Washington, during the winter of 1913 and 1914, there was a sharp epidemic of typhoid fever, due apparently to the pollution of a well supply by overflow of a stream which is known to have carried pollution. A hypochlorite plant was hastily installed and put in operation and this was followed by a quite definite and abrupt cessation of new cases of typhoid, since which time there have been no cases in Centralia, with the exception of certain hospital cases brought in from outside the community.

The results of hypochlorite treatment in Pittsburgh have indicated an improvement in typhoid conditions over and above that secured by filtration alone.

Hypochlorite was first applied in November, 1911. In that month there were 54 cases, in December 42, in January, 1912, there

were 20, and in February 5. From that time forward, the cases have remained for the most part less than 10 per month and have never again approached the high points of previous years. It is rare for the present high points to reach the former low points of the curve.

In Wilmington, Delaware, the excellent protection which disinfection affords was shown at the time of an epidemic of typhoid fever of about 250 cases at Coatesville, Pennsylvania, some 27 miles above Wilmington, upon the stream from which Wilmington draws its supply. The epidemic made its appearance in Wilmington, but was stopped short by the disinfection of the water supply.

The maximum dose of hypochlorite stated is 60 pounds per million gallons, which is at the Bubbly Creek plant in Chicago, where the nature of the water treated is well known to require a large dose. The lowest maximum quantity stated is 4 pounds per million gallons. The average of all the maximums stated for the various plants is 17 pounds per million gallons.

Bubbly Creek also shows the highest average dose of 55 pounds. The next highest is 35 pounds, and the lowest average dose stated is 3 pounds. The average of all the averages stated is about 11 pounds per million gallons.

Judging from the lack of information in response to inquiries bearing upon the relation between the quantity of hypochlorite required and the color or turbidity in the water, it seems that a surprisingly small amount of attention is given in the various cities to following out this relationship. A knowledge of this relation is of some importance, as it influences the quantity of hypochlorite that is required for a given water, the quantity that may be applied without producing objectionable tastes and the economy of the treatment.

The reason for the lack of attention to this point seems to lie in the fact that the cost of the hypochlorite required for any water is trifling and it is not of great importance just what quantity is applied, so long as it is enough, on the one hand, to give good bacteriological results, and, on the other hand, not so much as to produce objectionable tastes and odors.

The doses that fulfill these two conditions do not always coincide. The character of some waters is such that the dose which can be applied without contributing objectionable tastes and odors is more than enough to produce the desired bacterial reduction. With such

waters there is no difficulty in regulating the dose to give satisfactory results from every point of view. The character of other waters is such that the maximum dose which can be used without giving a taste is not enough to give the bacterial reduction required. This is the difficult condition to meet, and is found more frequently in raw waters than in filtered waters.

It is everywhere recognized that there are certain times when the hypochlorite treatment is less satisfactory than at others. This is shown principally in the appearance of tastes and odors that occasion complaint among consumers, or in a low and unsatisfactory removal of bacteria by the treatment. It occurs generally at a time when the turbidity or the color of the water increases greatly, or some other marked change, such as temperature, occurs in the condition of the untreated water.

Different waters vary a good deal in this respect, and but little information can be found which gives light upon the specific reasons for this variation and permits the formulation of general statements in regard to it.

An analysis of the figures at hand shows that in one place a maximum dose as great as 37 pounds per million gallons has not given rise to objectionable tastes or odors, and in numerous places 20 to 30 pounds has not been noticeable. The average amount stated for which no odor or taste was noticed was about 14 pounds per million gallons. The supplies in which it was definitely stated that no tastes or odors were noticeable included about 40 per cent of the total. Among the others there were general comments as to the occurrence of objectionable tastes or odors, indicating in the main that they are likely to occur with changes in the character of the water treated, especially at times of storm or freshet.

So far as is indicated by the somewhat incomplete data, the largest quantities of hypochlorite are used in those supplies in which the color or turbidity of the water are highest. Unfortunately, the information is not complete enough to enable any relationship to be established even in an approximate way between color, turbidity and quantity of disinfecting agents that may be used without objection.

DISCUSSION

MR. C. A. JENNINGS: About two years ago the speaker had a paper along the same lines before the Illinois Water Supply Association, and quoted statistics on typhoid death rates from a number of cities. The criticism was made of the paper at that time that the typhoid fever death rates were taken for periods anywhere from four to twelve years previous to the introduction of the disinfecting agent, and the typhoid data for only two or three years following—that is to say, whatever data were available since the introduction of the disinfectant were used. The point was made that great progress had been made in sanitation in the last few years, and that it did not give a fair comparison. If that criticism held in that paper it will also hold in Mr. Longley's paper. It may be well to weigh carefully the data received and not be too ready to place all of the credit to one charge. However, there is no argument against the statement that disinfection of water supplies has brought about a wonderful lowering of typhoid fever death rate, especially during the last four or five years.

MR. WM. M. JEWELL: The speaker has been very much interested in Mr. Longley's paper, and it seems that he has covered the statistics very well from a general standpoint, but he has not given the details that we need for laying out these works at various plants; in other words, the information is very general.

At Chicago, where the hypochlorite is used at one of the stations, it was found that about five or six times more hypochlorite was required for the sterilization than they could stand for, probably on account of the low temperature of the water; and that is a very important point that ought to be investigated by members of this section. It would be a good thing to have a committee on those features to report at the next meeting in order that the physical characteristics of introducing hypochlorite can be properly complied with. The members here would certainly like that information; those that are putting the plants in at least.

The paper states that the first use of hypochlorite was in 1908. In that connection will say that at the filter plant installed at the city of Adrian in 1897, the speaker used both hypochlorite of lime and sulphate of alumina, and prior to this chlorine gas was used on the testing plant.

Hypochlorite of soda and chlorine were first used on the Jewell filter at the Louisville Experimental Station about one year earlier, or in 1896; reference to Mr. Geo. W. Fuller's report of 1898 will substantiate this statement.

MR. M. B. LITCH: Will Mr. Jewell please state just what he meant by more than what the water could stand for?

MR. W. M. JEWELL: That is the statement that Mr. McDonough, the assistant commissioner of the public works, used, and presumably related to the odor, or the taste rather, if you can differentiate between the two in the case of hypochlorite of lime any more than you could with peppermint. He stated that at times of low temperatures the hypochlorite seemed to be undecomposed, and that therefore they could not get rid of the Coli; the amount used was five or six times more than was required under ordinary conditions of normal temperature at which times excellent results were obtained and the odor or taste, if any, would not be noticeable. Possibly there is a point, probably somewhere below normal temperature of the lake water, where the hypochlorite can be used efficiently and no odor or taste imparted to the water; whereas on the same water at a slightly lower temperature, such objections would exist and cannot be combated; at least in the light of our present knowledge of the way of using hypochlorite.

MR. H. P. LETTON: In 1911 Trenton, New Jersey, began to treat raw Delaware River water with hypochlorite. The state board of health carried on a series of examinations for the purpose of determining the proper dosage. At that time, which was during the winter, the water was cold and very high in turbidity and organic matter. The dose of chemical added was run up as high as 30 pounds per million gallons. Samples of the treated water taken an hour after the addition of the chemical, and tested for free chlorine, all gave negative results, although the water had an extremely disagreeable taste, and this taste persisted throughout the entire distribution system, and was especially noticeable in the hot water. The steam arising from a flowing hot water tap had a very strikingly unpleasant odor. From the tests made the conclusion was reached that the taste and odor were not those of the chlorine, but were due to some complex chemical change brought about by the action of the chlorine

on the organic matter present in the water. There was more or less complaint about the taste and odor at the time, but, as Mr. Longley's paper has shown, the chlorine treatment at Trenton reduced the typhoid death rate to a remarkable extent. A report on the tests mentioned and some statistical data regarding the effect of the treatment will be found in the 1912 report of the New Jersey state board of health.

MR. R. L. SACKETT: In the state of Indiana there is quite a wide variation in the geological conditions, which has permitted the smaller cities in the northern part to use well waters, but in the southern portion well waters are rare, and they have therefore quite generally used the surface waters of the Ohio River Valley. These waters are polluted in greater or less amounts. Some cities in Indiana have for several years been using water supplies for fire protection and street sprinkling purposes only, and not using them for culinary purposes. The state board of health found a portable apparatus for the installation of hypo treatment to be very valuable, and have equipped their laboratories with these simple temporary pieces of apparatus, which can be sent out to the smaller cities, and there hypo has been used, too much at times, and undoubtedly at other times too little, in cities where the water supply was without treatment at all, or where it was not satisfactory. These plants are inexpensive of course. They are manually controlled, and the question of the cost of hypo was not important. Very frequently the odor and taste of hypo were objectionable, but not so objectionable as the conditions which preceded it, and unquestionably this plan of the state board of health of placing in cities, practically without expense, as a temporary measure, these simple schemes for treatment with hypo has been of great value.

It is very difficult to collect data concerning the absolute influence upon mortality and morbidity, but the state board of health has been pretty well satisfied with its little propaganda, and feels that it has been of value. Many of these smaller cities have very gratefully accepted the tastes and odors as being the lesser of the evils until they could install better apparatus for the protection of their water supply.

MR. JOHN A. KIENLE: Mr. Jewell's remarks regarding the effect of the temperature of the water at Chicago producing taste and

odor recalls to the speaker's mind the conversation with the gentleman mentioned by Mr. Jewell, namely, Mr. McDonough, assistant mechanical engineer of the department of public works, and the speaker wishes to throw a little light on this subject.

In conversation Mr. McDonough stated that when the temperature of the water is down around 38° or 40° they are compelled to materially reduce the amount of hypo being applied. However, on numerous occasions, it was stated that the taste and odor prevalent in the city tap water were not due to an excessive quantity of hypochlorite actually being applied. In Chicago the application of hypo is made at the intake cribs, which are located a considerable distance out in the lake and the direction of the winds, as well as the state of the lake, due to these winds, necessitate the holding of the sludge in the tanks for a considerable length of time. This sludge sometimes accumulates to such an extent that they are compelled to dispose of it even under adverse conditions. At such times the action of the waves and the winds causes this sludge to be blown back into the crib and down into the shaft and tunnel. The result is a very noticeable taste and odor in the tap waters of the city fed from these particular cribs with the natural complaint from the citizens.

The writer believes that quite a little of this sort of trouble in Chicago has been due to the fact that close supervision could not be given to the operation of the hypo plant. In some instances there is not even telephone communication with the cribs. Under these conditions it is naturally to be expected that the attendants in charge of the hypo treatment are not familiar with the conditions prevailing in the city, and therefore cannot be quickly advised as to the best amount of hypo to be applied.

The question of temperature of the water also has its effect in other places; this being particularly the case at Milwaukee where the speaker is familiar with the operating conditions. In this city they normally apply during the spring, summer and fall months of the year, about six pounds of hypo per million gallons, but as soon as the water temperature goes down to about 40° they are compelled to cut the dose applied to as low as 3 pounds per million gallons; this being necessary in order to prevent taste and odors prevailing in the tap waters. At the times when this decreased dose is applied the bacteriological count runs up considerably and it is due to this fact, as well as the desire to prevent taste and odor, that

the use of liquid chlorine was recommended and a liquid chlorine plant recently installed.

It is rather difficult to give an absolute reason for the prevalence of taste and odor in these low temperatures following with application of hypochlorite of lime, except that it may possibly be due to the nondecomposition of the chloride solution. This is a chemical compound and it naturally has to be broken down in order to accomplish its bactericidal action, and if it is not broken down then the chlorine is carried right through with the lime and is undoubtedly responsible for the taste. It is a known fact that chloride solution will not readily decompose in water at low temperatures.

The question of organic matter affecting the taste and odor, the speaker believes is one that should be given careful consideration. In a great many cases where taste and odors prevail they are due, not to the liquid chlorine or to the hypochlorite, but to the decomposed vegetable or organic matter in the water. This was the case at East Chicago and the speaker knows of other similar instances, and he further believes that the nature and character of the organic matter in the water also have a decided effect on this question of taste and odor.

As an example he would cite the following: At the Notre Dame de Grace, District of Montreal, they have a rather peculiar condition of this kind. The water at this station is taken from the St. Lawrence River just below the junction of the Ottawa River with the St. Lawrence. During the winter months nothing but St. Lawrence River water reaches the intake of the station, yet when the spring freshets prevail the Ottawa River water rises very materially and the current from it is swept across the St. Lawrence into the intake of the pumping station. The Ottawa River is of an entirely different character from that of the St. Lawrence. It is a water that is quite high in color and in organic matter. It does seem, however, that the nature of this organic matter must be quite different from that which would be found in other waters. This is evidenced by reason of the fact that at this station they are applying liquid chlorine and when treating the St. Lawrence River water approximately four-tenths parts per million of available chlorine are required for sterilization. As soon as the Ottawa River water reaches the intake they are compelled to apply as much as one and one-half parts of chlorine per million, yet even with this high dose no taste or odor prevails.

In the operation of this plant sufficient chlorine is applied at all times to the intake so that they get a KI reaction on a sample of tap water taken from the discharge of the pump. The liquid chlorine, however, appears to be entirely dissipated by the time it has traveled several hundred feet from the station as no KI reaction can be obtained on samples taken at this point.

DR. D. P. CURRY: At Bowling Green, Kentucky, there were tastes and odors. At the plant they had but one mixing vat. The operator would start his pump and stirring device at the same time, pumping the sludge and all into the mains. At that time they were doing some work on the mains, and there was considerable disturbance of the sediment in them. The odor and taste of the hypo were extreme. Was not this due to using the milky mixture rather than the sedimented clear solution?

MR. JOHN A. KIENLE: Regarding the last gentleman's remarks the speaker would say that at Pittsburgh they are applying the hypochlorite powder directly and in a very crude way and so far as he knows excellent results have been obtained without the prevalence of taste and odor. In other words, at this plant they do not attempt to take out any of the sludge or even settle it. The application is made simply by shoveling the powder into the water of the clear well at regular intervals. This therefore is one instance where the sludge does not worry them apparently.

MR. H. P. LETTON: The speaker knows that a year or two ago the East Jersey Water Company, at their filtration plant at Little Falls, New Jersey, treated the filtered water with hypochlorite, which was fed in as a milky solution, the lime being kept in suspension by a stirring device. No tastes or odors resulted from this practice.